A New Era in Push-Pull Amplification*

A Push-Pull Power Amplifier of New Design

By JOSEPH RILEY

IT has been a long while since we have heard much of push-pull amplifiers; they had just about passed out of existence. Now comes a revival, but the push-pull amplifier this time appears in a new dress. It is designed expressly for sets having an output of very large energy, and will take care of any receiver, including the largest superheterodynes. This amplifier uses two power tubes of the 171 type in the push-pull stage and, with only 180 volts "B" supply, is capable of delivering the same amount of output energy to the loud speaker as one 210-type power tube using 350 volts "B". The transformers and the impedance employed are of new design and have excellent frequency characteristics.
—Editor.

LONG before the ordinary radio fan took an intense interest in quality reproduction, the Western Electric Company's engineers were devising bigger and better audio-frequency amplifiers. The result of their work was the push-pull amplifier, which, because of its excellence, created quite a sensation when it was put on the market several years ago. At that time there was available no other type of amplifier which could even run a race with it. Anyway, as the story goes, or should go, these wise engineers were ahead of the game, as they usually are, and knew just a bit too much about audio-frequency amplification to suit many rivals.

One out of every fifty or so radio fans acquired about half an idea as to what the talk of push-pull amplification was all about; the other forty-nine or so remained in ignorance or were completely deluded by the very astonishing articles published on the subject. These articles were much like the premature report of the death of Mark Twain: very much exaggerated. At any rate, what counted most was results; and adding a push-pull amplifier to a set of early vintage was like moving the German street band off the block and substituting the Philadelphia Symphony Orchestra. Judging by the enthusiasm created by the push-pull amplifier, the foregoing simile is not exaggerated.

WHY "PUSH-PULL"?

What did the push-pull amplifier actually do to better reproduction so much? Any radio fan will tell you that it push-pulled; but that is not exactly the definite answer one might expect. In the first place, the real and original push-pull amplifier used the first power tubes deserving of the name. Today, almost every fan knows that, if any of his audio-frequency amplifier tubes is overloaded by excessive input energy, the result is a nasty form of distortion. If a big "he-man" tube is used in the last stage of amplification, there is very little chance of overtaxing it with the energy output from the average receiver; the tube is perfectly capable of handling "power" without muddling it. All this has a great deal to do with what we call *"grid swing"* and, in any audio tube, we always want to be sure that

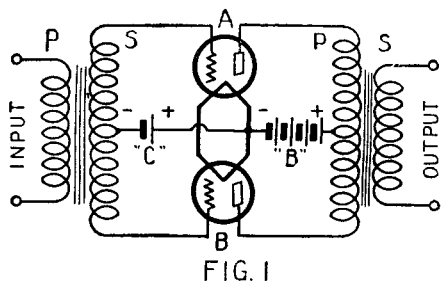


FIG. 1

The basic circuit of a push-pull amplifier as originally devised.

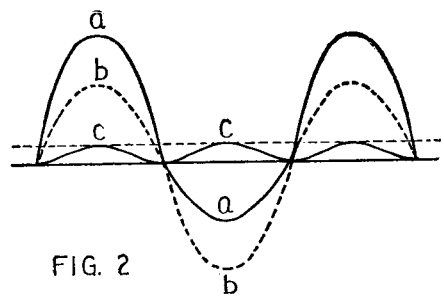
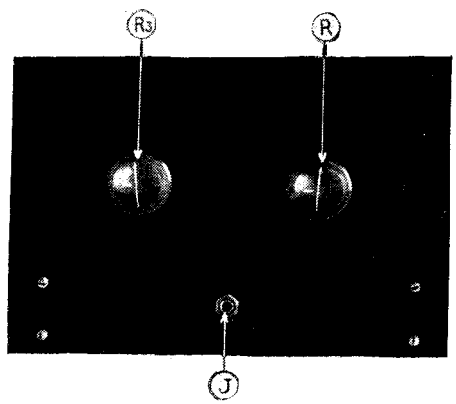
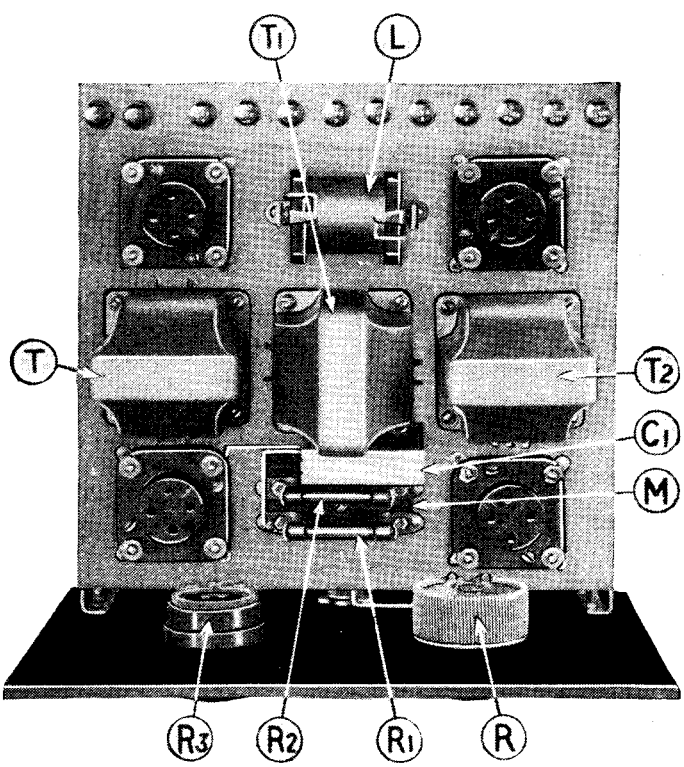


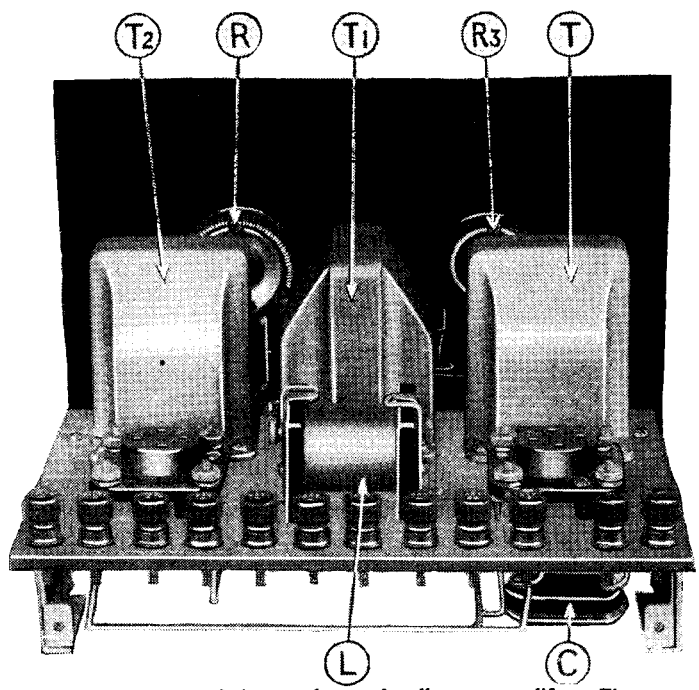
FIG. 2

These curves show, a, the A.F. output current wave as amplified by a transformer; b, the fundamental wave and c, the harmonic. The action of the push-pull circuit is such as to eliminate the harmonics thus introduced.



A panel view of the completed push-pull power amplifier. R is the power rheostat, R3 the volume control and J the loud-speaker jack.





Top and rear views of the complete push-pull power amplifier. The parts are: R, filament rheostat; R1, plate resistor; R2, grid resistor; R3, volume control; M, resistor mounting; L, R.F. choke; C, by-pass condenser; C1, coupling condenser; T, A.F. transformer; T1, push-pull A.F. transformer and T2, push-pull output impedance.

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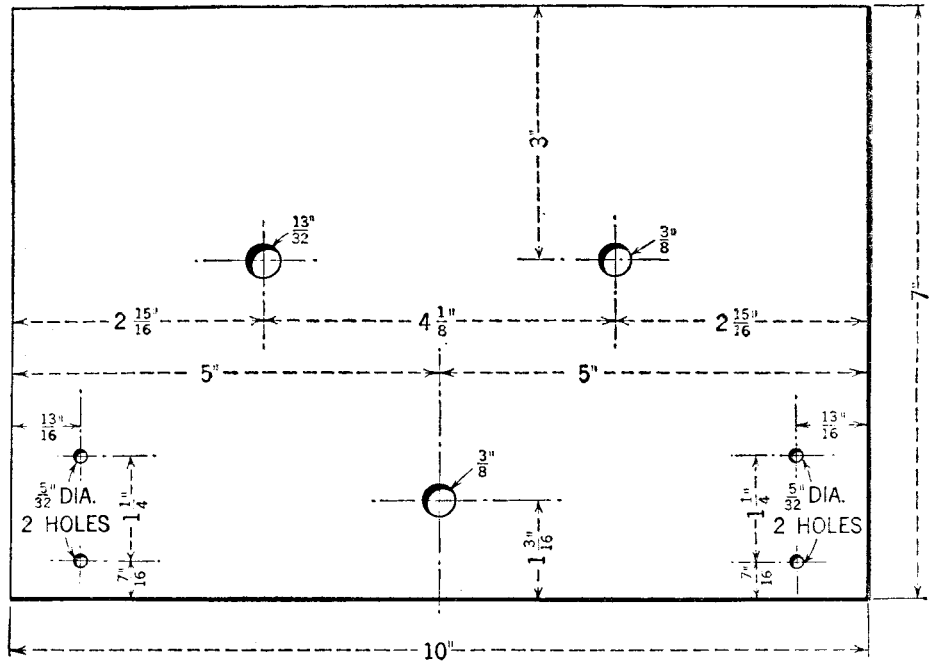
the grid of the tube is not allowed to "go positive"; for as soon as it does we get very unequal amplification, or a rectification, which in itself is a form of distortion. That is why we use power tubes with high "B" and "C" voltages.

The push-pull amplifier used three power tubes (we would call them semi-power tubes today); one for the first and two in the second stage of audio. The last two *were not connected in parallel,* as so many radio fans seemed to imagine. Here is how it was done.

The first audio tube worked into a push-pull transformer which had an orthodox primary winding, but a very unorthodox secondary coil. The secondary was really one long winding with a tap taken off at its exact center. One end of the secondary was connected to the grid of one of the last two tubes, and the other to that of the final tube. The center tap connected to the negative filament leg, or to the negative post of a "C" battery. The next push-pull transformer had an orthodox secondary, but a primary with a center tap. The plates of the two last tubes connected to the outside primary terminals, and the center tap to the positive post of the "B" battery. The total work to be accomplished was equally distributed between the last two tubes; that is, each tube took care of one half of the cycle, while in the usual amplifier one tube handles the whole.

This arrangement is obviously an advantage, as there is practically no chance of overloading, but the push-pull amplifier accomplishes even more than this. It absolutely abolishes the harmonic and amplifies only on the fundamental frequency. Let us get a better understanding of this.

In the first place, there is a definite output current, which, after passing through the transformer, resolves itself into the fundamental and a harmonic of the fundamental. This harmonic, which is artificially created, is undesirable, as it can introduce serious distortion. All this is delineated in Fig. 2, where *aa* is the undistorted output current wave, *bb* the fundamental and *cc* the harmonic. Referring to this diagram and that of Fig. 1, it is obvious that the wave shapes in both tubes (A and B) are identical, but that the fundamental *bb* in tube B is 180 degrees out of phase with the fundamental wave *bb* in tube A, while the harmonic is in phase in both tubes, as it varies merely in amplitude. In consequence, the fundamental waves as amplified by the two tubes are additive in the output circuit, while the harmonic waves, being in phase, will neutralize each other. The resultant output to the loud speaker is an amplified reproduction of the fundamental wave only.



Layout and drilling plan for the panel of the push-pull power amplifier. All the necessary dimensions are given.

A NEW AMPLIFIER

We admit, without even being questioned, that the original push-pull amplifier was a big step ahead and certainly worth the money, if it was well made; but push-pull amplification suffered a good deal of discredit because of the inferior apparatus placed on the market by some manufacturers, and also because of lack of knowledge on the part of radio fans concerning the system. This, coupled with the fact that since then there have become available very fine power tubes, improved A.F. transformers, impedances and so on, helped to shove the push-pull amplifier into the background. Now, here we are with a bit of momentum behind us, all set to push or pull the push-pull amplifier into the limelight again. And with good reason, for we have with us one of these amplifiers, employing two of the new 171-type power tubes in the last stage, a push-pull transformer of new design with large iron core and high impedance primary, and a new design push-pull output impedance. There are actually three stages in this amplifier. The first or input stage is of the resistance-coupled type, noted for its undistorted amplification; the second is of the transformer-coupled type. The transformer used has excellent characteristics and is capable of amplifying the low notes. These two stages, working together in the order outlined, show a frequency curve which is very nearly flat. The last stage, of course, is the push-pull and, by virtue of the system and the new design of transformer and impedance, completes the amplification without altering the excellent frequency curve obtained in the first two stages.

As previously mentioned, two of the 171-type power tubes are desirable in the push-pull stage. If the very best results are desired this type should be used, with a 112-type semi-power tube in the second stage and a 201A-type tube in the resistance-coupled stage. However, it is not absolutely necessary that this combination be carried out, as good results can be had from other tubes. Dry-cell tubes can be used;

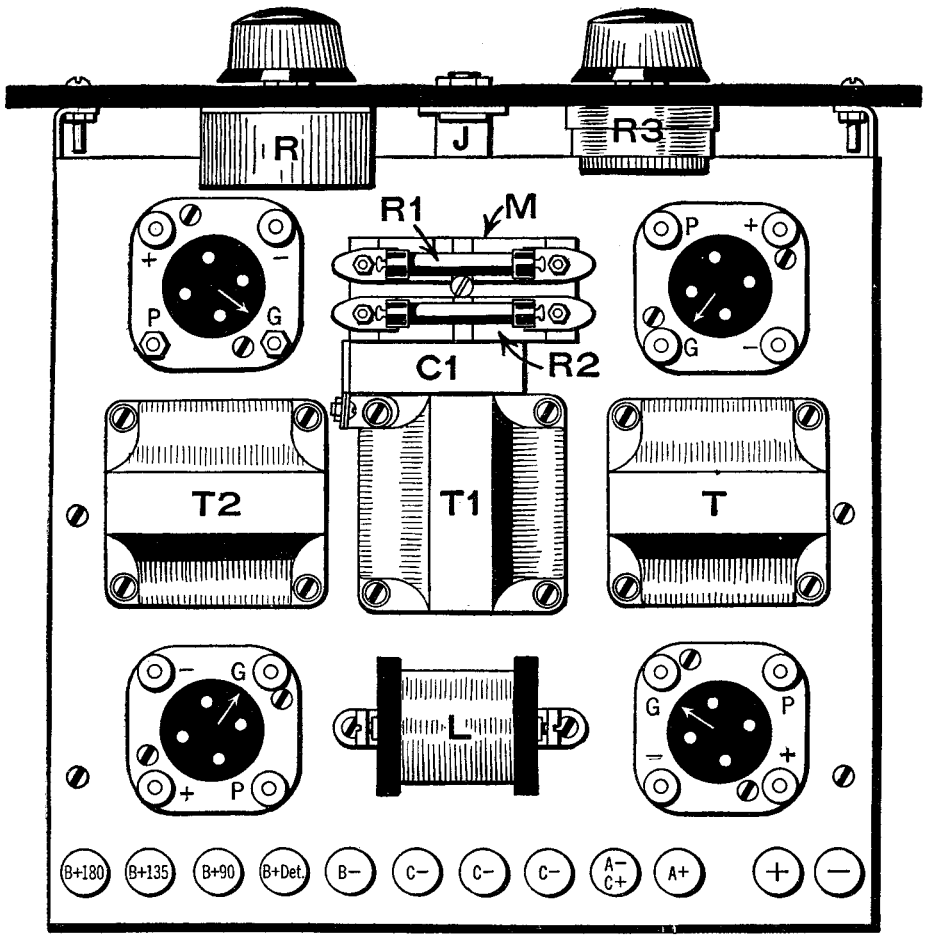
SYMBOL	Quantity	NAME OF PART	VALUE OF PART	REMARKS	MANUFACTURER ★	
L	1	R. F. choke	85 MH		1	12,13,28
T	1	A. F. trans.	3 to 1		1	
T1	1	A. F. trans.		Push-pull type	1	
T2	1	Impedance		Push-pull type, output	1	
C	1	Fixed Condenser	.0005 mf.	By-pass	2	3,5,7,14,29,30
C1	1	Fixed Condenser	.1 mf.	Coupling condenser	3	2,5,7,14,29,30,32
R	1	Rheostat	6 ohms	Power type	4	7,15,16,17,20
R1	1	Resistor	.1 meg.	Plate resistence	5	3,6,14,18,19
R2	1	Resistor	1. meg.	Grid resistance	5	3,6,14,18,19
M	1.	Res. mounting		Double mounting	6	5,14,18
R3	1	Potentiometer	500000ohms	For volume control	5	4,7,16,17
J	1	Jack		Single circuit filament control	7	4,16,20
	4	Sockets		UX type non-microphonic	8	9,12,15,20,27
	12	Binding posts			9	15,21
	1	Panel		7 X 10 X 3/16"	11	22,23,31
	1	Sub-panel		8½ X 9 X 3/16"	11	22,23,31
	2	Brackets			8	
V	1	Tube	5 v. ¼ amp	201-A type	10	24,25,26
V1	1	Tube	5 v. ¼ amp	112 type	10	24,25
V2,V3	2	Tubes	5 v. ½ amp	171 type	10	24,25,26
		Hookup wire				

NUMBERS IN LAST COLUMN REFER TO CODE NUMBERS BELOW.

1 Samson Electric Co.
2 Sangamo Elec. Co.
3 Tobe Deutschmann Co.
4 H. H. Frost, Inc.
5 Electrad, Inc.
6 Arthur H. Lynch, Inc.
7 Carter Radio Co.
8 Benjamin Elec. Mfg. Co.
9 H. H. Eby Mfg. Co.
10 C. E. Mfg. Co. (Ceco)
11 Micarta Fabricators
12 Silver Marshall, Inc.
13 Bremer-Tully Mfg. Co.
14 Aerovox Wireless Corp.
15 General Radio Co.
16 Yaxley Mfg. Co.
17 Central Radio Labs.
18 Int. Res. Co. (Durham)
19 Dubilier Condenser Corp.
20 Pacent Elec. Co.
21 X-L Radio Labs.
22 Amer. Hard Rubber Co.(Radion)
23 Insulating Co. of Amer.(Insuline
24 Radio Corp. of America
25 E. T. Cunningham, Inc.
26 Magnavox Co.
27 Grey & Danielson (Remler)
28 Precision Coil Co.
29 Wireless Spec. Apparatus Co.
30 Sprague Electric Co.
31 Diamond State Fibre Co.
32 Potter Mfg. Co.

If you use alternate parts instead of those listed in the first column of manufacturers, be careful to allow for any possible difference in size from those originally used in laying out and drilling the panel and sub-base.

★THE FIGURES IN THE FIRST COLUMN OF MANUFACTURERS INDICATE THE MAKERS OF THE PARTS USED IN THE ORIGINAL EQUIPMENT DESCRIBED HERE.



Layout of the apparatus on the sub-base. The parts carry the same symbols as in the other illustrations.

two of the 199 type for the first and second stages, and two of the 120 type for the push-pull stage. As for storage-battery tubes, a very good combination is obtained by using two 201A-type tubes, with two 112's in the push-pull stage, or even 201A tubes throughout. Still, it should be kept in mind that if *real* results are desired, the combination of tubes specified should be used.

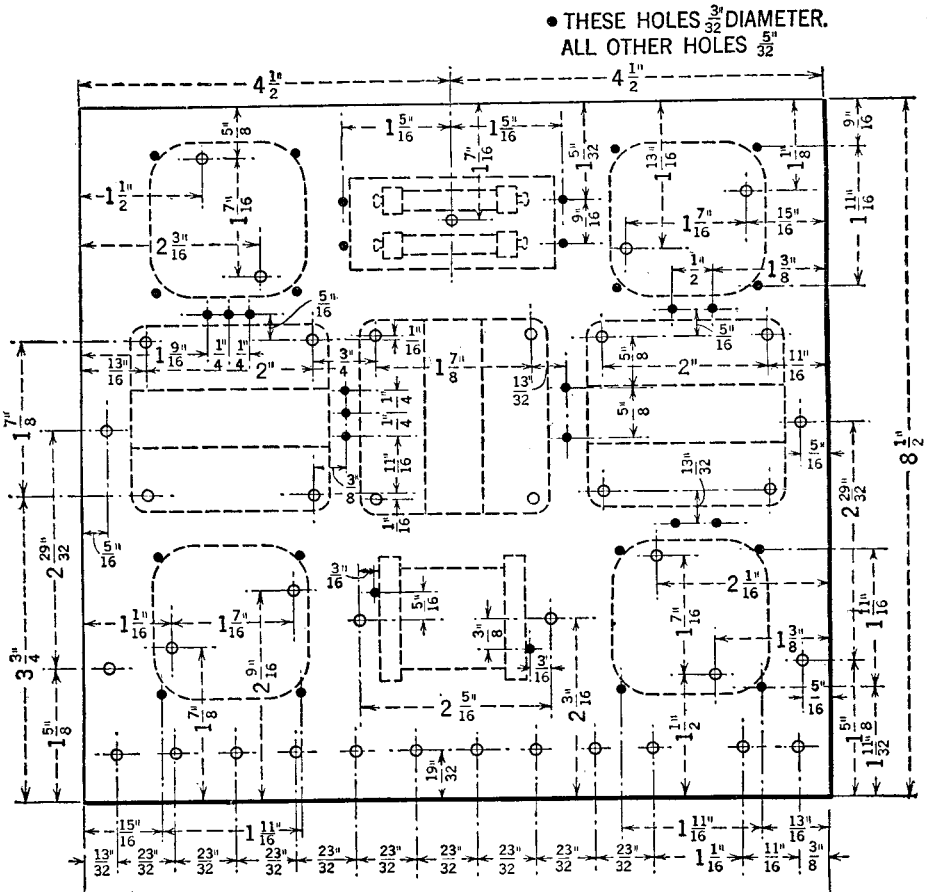
Whatever tubes are utilized, it is best to apply the "B" voltages specified by the manufacturer. This is important, for if the "B" voltages are too high the tubes cannot function properly. Take note of the fact that rather a high "B" voltage is supplied to the detector tube through the detector post on the amplifier; this for the reason that there is a large drop in voltage across the plate resistor of the first-stage amplifier, which is in series with the plate of the detector tube. The correct voltage here depends a great deal upon the type of detector tube used; it is a good idea to try voltages ranging from 90 to 135.

VOLUME WITH QUALITY

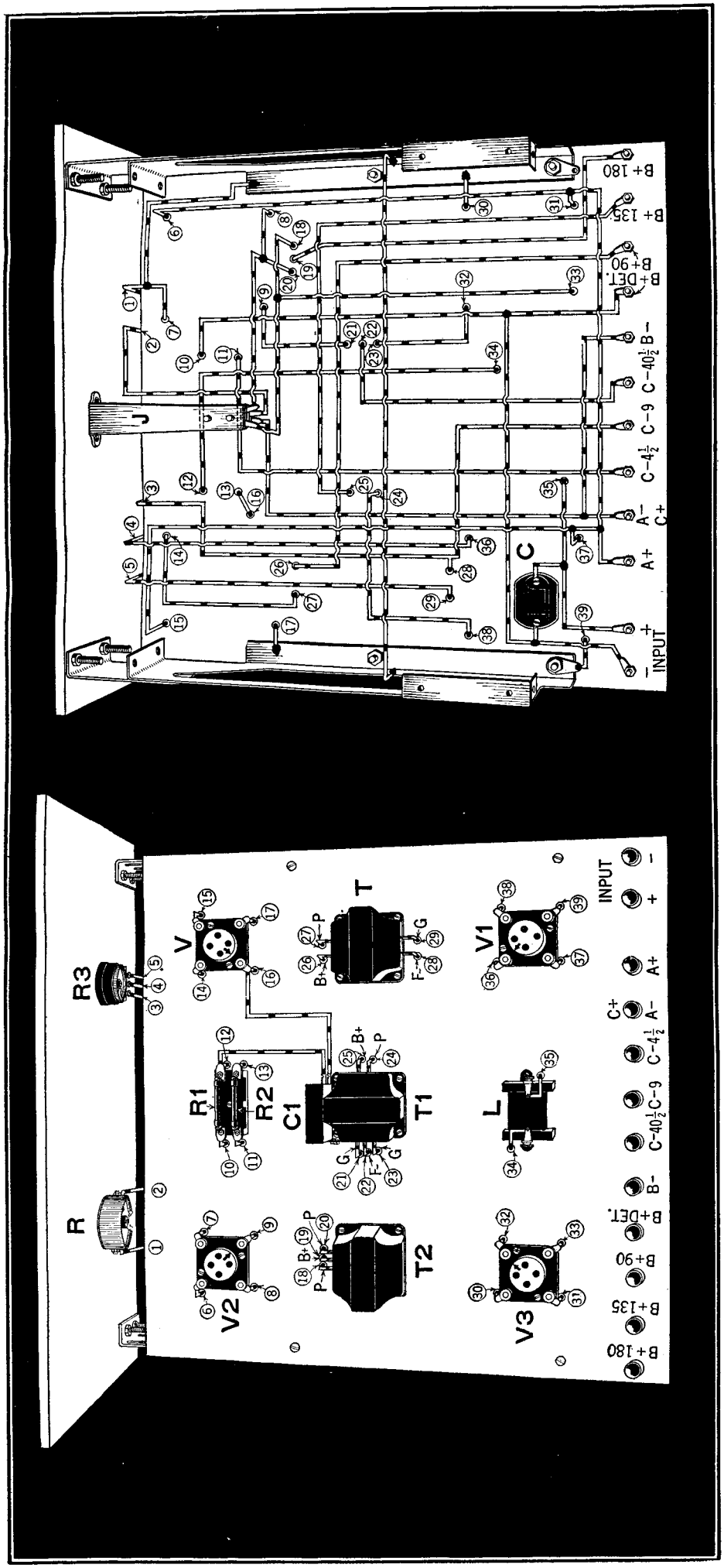
The importance of this amplifier lies in its ability to handle energy without "smearing" it or, in other words, to provide undistorted reproduction with immense volume; an output that can equal the volume of a full orchestra, should you want it. And there are many people who do, for it is just at this point that real tonal results become available. Whether you want this quantity of sound or not, certainly it is a pleasure to have an audio amplifier that will handle all of the output energy from your receiver. Most amplifiers will not; that is why we have power amplifiers. If an amplifier cannot handle the output energy from the receiver, the sounds will not seem natural.

The present push-pull amplifier has been designed with two ideas in mind relative to its adaptability. First, its electrical characteristics are such that it can be used with any type of radio receiver, irrespective of the type of detector tube used. This is not true of all audio amplifiers. Secondly, it is made in compact form, so that it will not hog space, but can be placed at some distance from the receiver itself to eliminate electrical coupling between them. It operates independently of the receiver; that is, it does not go into operation until the speaker is plugged into the jack on the panel. When the speaker plug is pulled out the tubes are automatically turned off. If the user does not like this idea, the speaker may be left connected and the amplifier turned off by turning the single rheostat knob full to the left. This single rheostat, which controls all four tubes, is of the power type with very heavy resistance wire. The volume can always be controlled by the knob on the left of the panel; this governs a 500,000-ohm potentiometer, which regulates the effective voltage reaching the grid of the second amplifier tube. Thus, the volume can be increased from a whisper to a roar; and when we say roar we don't mean blast.

In order that this push-pull power amplifier may operate at maximum efficiency, a radio-frequency choke L, with a value of 85 millihenries, is placed in the plate lead of the detector tube and by-passed by a fixed condenser C, of .0005-mf. capacity. Because of this arrangement, none of the radio-frequency currents can get into the audio-frequency circuits. Usually, a good deal of this current passes by the detector tube without being rectified, and is detrimental to the operation of the audio amplifier if it is allowed to leak into these circuits. The R.F. choke blocks its passage in this direction, but the fixed condenser offers it a free path to the filament end of the detector circuit, which is the normal



Complete dimensional and drilling details for the sub-base. The parts are shown in dotted lines to make the drawing more easily followed.



point for the completion of the R.F. circuit. The R.F. choke, however, does not obstruct the passage of the rectified currents, while the capacity of the by-pass condenser is too low to allow these audio-frequency currents to leak off. Consequently, they are passed on to the audio-frequency circuits and are amplified by them.

OUTPUT DEVICE

Another point of interest is that the loud speaker is fully protected at all times, as the output impedance arrangement does not allow the heavy direct current of the plate circuit to flow through the loud-speaker windings. This also allows the loud speaker to operate more freely. The usual blocking or stopping condenser employed in output filters is not necessary in this case; as the "B" battery current feeds into the center of the output impedance, through the center tap, and can find a complete circuit only through the plate circuits of the two power tubes.

The construction of this amplifier is comparatively simple, the accompanying wiring

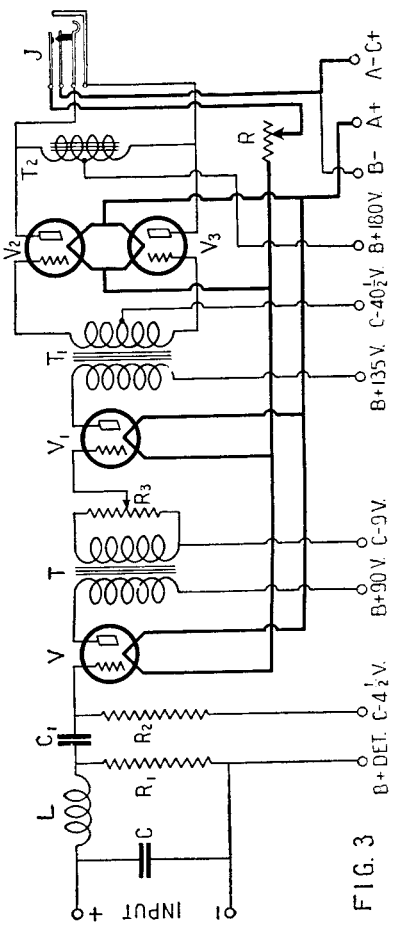


FIG. 3

Above, the complete schematic wiring diagram of the push-pull power amplifier. At left, the pictorial wiring diagrams, showing, at top, the sub-base wiring, and beneath, that on the panel and upper side of sub-base. The hole through which each lead passes is numbered alike in both views, so that every connection may be readily traced.

and constructional drawings giving all the necessary details. The panel carries the rheostat, the volume control and the loud-speaker jack. The rest of the apparatus, except for the fixed by-pass condenser C, is mounted on top of the sub-base. It will be noted that practically all of the wiring is completed on the underside of the sub-base. This makes a neat job and at the same time is most satisfactory from the electrical standpoint.